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B70 09088

SUBJECT: Manned Space Flight Network Station Reliability Considerations for Skylab Support - Case 900

DATE: September 30, 1970

FROM: B. F. O'Brien

ABSTRACT

Station reliability in the Manned Space Flight Network is considered in light of the potential loss of coverage caused by a station failure during a Skylab mission. Station availability data was obtained from reports prepared by the Applied Physics Laboratory of the Johns Hopkins University for GSFC, and a brief description of their study is given. By applying this data to the results of a simulated Skylab mission, it was concluded that two critical stations, Hawaii and Santiago, could be expected not to be available when called upon to provide functional support during one or two revolutions in which they would be providing unique contact during the mission.

(NASA-CR-113653) MANNED SPACE FLIGHT NETWORK STATION RELIABILITY CONSIDERATIONS FOR SKYLAB SUPPORT (Bellcomm, Inc.) 11 p

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MEMORANDUM FOR FILE

Consideration is being given to reducing the number of stations in the Manned Space Flight Network (MSFN) for support of Skylab missions. In a prior study, J. P. Maloy[1] has indicated that the number of stations could be reduced from 12 to 9 or 10 with little degradation of network coverage. However, the omission of two or three sites could reduce the amount of redundant coverage, and would extend certain periods of no-coverage. This situation places a greater dependence on the remaining stations to provide the required coverage, and increases the effect of station reliability on the over-all communication system performance.

Reliability estimates for the MSFN stations have been obtained from a recent report[2] by the Applied Physics Laboratory (APL) of the Johns Hopkins University prepared for Goddard Space Flight Center. The APL report is the fourth in a series devoted to the assessment of the operational reliability of the MSFN. While this report deals primarily with the reliability of the network of stations during a given mission, it also presents information on stations according to their category: single channel station, dual channel station and the prime-plus-wing station.

The reliability estimates make use of a cumulative data base that extends from missions AS-205 (Apollo 7) to AS-508 (Apollo 13). The data base consists of "red" (no go) and "green" (go) Station Status Reports as submitted to the Network Operations Manager. A red report is further qualified to indicate whether the station can support with impaired but satisfactory performance, or through the use of substitute equipment. A "red-can support" report would not be considered a failure for the purposes of computing a station failure, but would obviously be a failure at the equipment level.

Station reliability is measured in terms of four major mission support functions, rather than equipment operation:

I Tracking and Navigation

II Voice Communications

III Monitoring of Systems

IV Uplink Data and Commands

Each of these functions is composed of several sub-functions, all of which must be "green" or "can support" in order for the major function to be considered green or supportable. A computer-based reliability model is used to translate an equipment failure into sub-function and function failures. Since an individual equipment can contribute to two or more mission support functions, it is possible for a single equipment failure to result in the loss of more than one support function. Alternatively, simultaneous equipment failures could result in the loss of only one function if the equipments were used for supporting only that function.

Two major statistics were computed by APL as measures of functional reliability: (1) availability and (2) mean-time-between-failures (MTBF). The MTBF is computed by dividing the operating time (as measured in mission-support-function hours) by the number of failures experienced at the function level. Availability is estimated as the ratio of operating time to total mission time. As examples, an availability of 0.9 can be taken to mean that the station was capable of performing a given function 90% of the time. Similarly, an MTBF of 200 hours means that on the average the station experiences an interruption of the function every 200 hours. It has been assumed for the purpose of computing operating time, that all equipment is operating for the duration of a mission unless it is explicitly reported down or not in use.

Using the cumulative data bases from AS-205 through AS-507, APL has made reliability predictions for AS-508, and has compared them with the observed reliability. The cumulative availability and MTBF for a station category is computed after each mission, based upon all observations available. These computations are then used as the best estimate of the performance expected during the next mission. Tables 1A through 1D, taken from the APL report, summarize the predicted and observed availability and MTBF for the average station, the single channel station, the dual channel station and the prime-plus-wing station. Table 2 from the APL report lists the MSFN stations providing data for the report, and their classifications.

Although these tables may prove useful in assessing a station's support capabilities, the prediction of the reliability of the entire network becomes very complex because a station supports the spacecraft for only a small percentage of its total operating time. Therefore, every station functional failure will not necessarily result in a network functional failure. This is further complicated by redundant coverage at various times, and periods of no coverage at all. In estimating network reliability, APL takes these factors into account in their computer model, which is revised for each mission. Additional considerations not included in the APL study is the reliability of the NASCOM network including circuits and switching centers. A reliability performance analysis of the circuits and the Univac 494 switching computer at Goddard Space Flight Center is published monthly,(3) but no overall figure of merit is computed for the communication function between a given station and the Mission Control Center.

Data from Mr. Maloy's Skylab coverage study indicates that for a 56-day (808 revolutions) mission at 235 nautical miles altitude and an orbital plane inclination of 50°, there will be thirteen revolutions in which there is only one contact of at least three minutes between the spacecraft and a ground station. In each case, the contact would be made by the proposed Santiago site. In addition, there would be 90 revolutions with only one contact of at least six minutes, and sixteen revolutions in which there would be no contacts of at least six minutes. Fifty-six of the unique contact times would be provided by Hawaii, while thirty-six would be provided by Santiago. This contact data was found to be true for both the twelve-station network, and the nine-station network. A six-minute contact is required to dump data from the Skylab tape recorder, while a contact time of at least three minutes is considered a reasonable requirement for voice communication and collection of real-time telemetry data.

The above figures are in agreement with Mr. Maloy's conclusion on the importance of Hawaii and Santiago is providing adequate coverage. Hawaii is a dual channel station, and it is assumed that the proposed station at Santiago or an alternate location will also be a dual channel one. The predicted functional availability for this type of site is 99.6% for tracking and navigation (I), 99.2% for voice communications (II), 97.6% for monitoring of systems (III), and 98.1% for uplink data and commands (IV). It can be concluded that on the average, for repeated 56-day missions, that either Hawaii or Santiago would not be available when called upon to support functions I and II on approximately one revolution, and functions III and IV on approximately two revolutions during the 90 revolutions when they provide unique coverage for at least six minutes. The number of times that functional support would not be available on revolutions with a single contact of at least three minutes would be much less, since there are only thirteen such revolutions in a 56-day mission.

B. F. O'Brien

2034-BFO-pjr B. F. O'Brien

REFERENCES

1. Maloy, J. P., "Effect of Manned Space Flight Network Reduction on Skylab Support", Case 900, May 22, 1970.

2. Lee, F. N., Mylnarczyh, R. H., and Seneca, V. I., CSC 1-200 "Manned Space Flight Network Operational Reliability Assessment for Apollo Mission AS-508", July 1970.

3. "NASCOM Network Ground Communications Reliability Report", by NASA Communications Division, GSFC.

TABLE 1A

AVERAGE STATION AVAILABILITY AND MTBF

FOR FLIGHT PHASE APOLLO 13

Major Function*		Availability: Lower 95% Limit	Availability: Mean	Availability: Upper 95% Limit	Time-to-Failure: Lower 95% Limit	Time-to-Failure: Mean	Time-to-Failure: Upper 95% Limit
I	Observed		.98688		107.75	169.23	311.91
	Predicted		.98455			163.34	
II	Observed		.99894		361.08	856.48	4818.47
	Predicted		.99252			428.13	
III	Observed		.99779		130.13	213.88	429.79
	Predicted		.98202			203.10	
IV	Observed		.95960		75.18	109.70	177.96
	Predicted		.98117			124.48	

* I Tracking and Navigation

II Voice Communications

III Monitoring of Systems

IV Uplink Data and Commands

TABLE 1B

AVERAGE SINGLE-CHANNEL STATION AVAILABILITY AND MTBF

FOR FLIGHT PHASE APOLLO 13

			AVAILABILITY			TIME-TO-FAILURE	
Major Function*		Lower 95% Limit	Mean	Upper 95% Limit	Upper 95% Limit	Mean	Upper 95% Limit
I	Observed		.96525		60.28	110.35	280.07
	Predicted		.97126			148.12	
II	Observed		.99755		190.35	570.20	11071.76
	Predicted		.98714			382.13	
III	Observed		.99645		73.46	142.39	416.80
	Predicted		.97617			258.55	
IV	Observed		.97610		47.11	79.70	168.82
	Predicted		.96947			128.39	

* I Tracking and Navigation

II Voice Communications

III Monitoring of Systems

IV Uplink Data and Commands

TABLE 1C

AVERAGE DUAL-CHANNEL STATION AVAILABILITY AND MTBF
FOR FLIGHT PHASE APOLLO 13

		AVAILABILITY			TIME-TO-FAILURE	
Major Function*	Lower 95% Limit	Mean	Upper 95% Limit	Lower 95% Limit	Mean	Upper 95% Limit
I Observed		.99858		113.32	237.83	872.75
Predicted		.98592			114.85	
II Observed		.99942		238.38	714.07	13865.52
Predicted		.99234			238.75	
III Observed		.99942		238.38	714.07	13865.52
Predicted		.97594			130.62	
IV Observed		.99935		92.09	178.51	522.52
Predicted		.98133			102.89	

* I Tracking and Navigation

II Voice Communications

III Monitoring of Systems

IV Uplink Data and Commands

TABLE 1D

AVERAGE PRIME PLUS WING AVAILABILITY AND MTBF

FOR FLIGHT PHASE APOLLO 13

		Availability			Time-to-Failure		
Major Function*		Lower 95% Limit	Mean	Upper 95% Limit	Lower 95% Limit	Mean	Upper 95% Limit
I	Observed		.99623		90.02	213.54	1201.34
	Predicted		.99998			943.57	
II	Observed		1.00000		142.90	N/A	Infinity
	Predicted		1.00000		1258.12	N/A	Infinity
III	Observed		.99689		67.88	142.45	522.77
	Predicted		.99997			529.18	
IV	Observed		.87136		48.18	93.39	273.36
	Predicted		.99653			179.11	

* I Tracking and Navigation

II Voice Communications

III Monitoring of Systems

IV Uplink Data and Commands

TABLE 2

MSFN STATIONS PROVIDING DATA FOR THIS REPORT

Code Name(s)	Number	Location	Classification
MIL	2	Merritt Island	Dual, 30-Foot
BDA	6	Bermuda	Single, 30-Foot
CYI	8	Canary Island	Single, 30-Foot
ACN	9	Ascension Island	Dual, 30-Foot
MAD, MADX	10	Madrid	Dual + Wing, 85-Foot
CRO	13	Carnarvon	Dual, 30-Foot
HSK, HKSX	15	Canberra	Dual + Wing, 85-Foot
GWM	16	Guam	Dual, 30-Foot
HAW	17	Hawaii	Dual, 30-Foot
GDS, GDSX	19	Goldstone	Dual + Wing, 85-Foot
GYM	20	Guaymas	Single, 30-Foot
TEX	22	Texas	Single, 30-Foot